Reviewer: John P. Knezovich, PhD
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Review of the Draft Report:
Water Quality Criteria for Permethrin
Phase III: Application of the pesticide water quality criteria methodology
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Overview
The freshwater criteria for permethrin (3-phenoxyphenyl) methyl 3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate) defined in this draft report was derived using methodology recently developed by Tenbrook *et al*. (2009)[1]. The methodology considers relevance of the endpoints and quality of the data in derivation of the criteria. This methodology was motivated by the California Regional Water Quality Control Board's desire to employ rigorous methods to develop criteria for protection of the Sacramento and San Joaquin River Watershed.

Basic information and physical-chemical data
The report provides a comprehensive summary of the physical-chemical data for permethrin. This data set is straightforward and indicates that this pesticide has low solubility, high density, low volatility, high ability to bioaccumulate, and is moderately persistent in aqueous environments (i.e., slow rates of hydrolysis, moderate rates of photolysis and biodegradation). This pesticide's physical-chemical characteristics make its exposure to aquatic organisms a relevant concern.

Human and wildlife dietary values
The FDA has not set action levels for permethrin in fish tissue.

Avian mortality does not appear to be a concern for permethrin as the NOEC for mallard ducks is 125 mg/kg and the LOEC is 500 mg/kg based on concentrations in feed. (Concentrations should be consistently reported in metric units and not ppm).

Ecotoxicity data and data reduction
The authors evaluated 155 published studies of permethrin toxicity to develop the proposed criteria. Relevance was determined using the aforementioned criteria[1] and data for studies that were deemed acceptable were evaluated. Adequate and reliable data is available for determining acute toxicity using animal studies and exclusion criteria appear to have been applied properly. Fourteen acute, 3 chronic, and 6 mesocosm studies were found to contain relevant and reliable data.

The final acute data set contains 19 species mean acute toxicity values (SMAV) and the final chronic data set contains 3 species mean chronic values (SMCV). The criteria used

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[1] P. Tenbrook *et al*. (2009). *Methodology for derivation of pesticide water quality criteria for the protection of aquatic life in the Sacramento and San Joaquin River basins. Phase II: Methodology development and derivation of chloropyriphos criteria.* Report prepared for the Central Valley Regional Water Quality Control Board, Rancho Cordova, CA.

for data reduction (e.g., preference for flow-thorough tests, sensitive species) are appropriate and appear to have been correctly applied.

Acute criterion calculation
The acute criterion for permethrin was calculated using methods defined by Tenbrook *et al*. (2009). The five taxa required for the species sensitivity distribution (SSD) were available and the species sensitivity distribution (SSD) method was used. The Burr Type III SSD method was used to derive the median 5th and 1st percentile values. The median 5th percentile value was used in accordance with the Tenbrook et al. (2009) methodology to derive an acute criterion of 10 ng/L. These calculations appear to have been correctly performed.

Figure 2 appears to have an incorrect label on the *y* axis. This axis appears to represent the frequency of studies, not probability.

Chronic criterion calculation
The acute-to-chronic ratio (ACR) method was used to derive the chronic criterion. Only two data sets were rated as reliable, which only satisfied two of the five taxa requirements. A saltwater species (*Americamysis bahia*) was used in accordance with the methodology to calculate an ACR, but data for two additional acutely sensitive species was not available. A species mean acute to chronic ratio (SMACR) for measured data was calculated by dividing the acute LC50 value by the chronic MATC value.

This section needs to include more information on the derivation of the criterion. Specifically, the authors need to:

1) Define the source of the default values were used for the second and third ACRs;
2) Be consistent: the ACR for *A. bahia* is referred to as the “species mean ACR (SMACR)” on page 8, but is identified as the ACR in Table 8;
3) Reference the source of the default values used in Table 8. These values have a profound effect on the final multi-species ACRs and their use needs to be justified; and
4) Use the same number of significant figures for the ACR as for the acute 5th percentile value.

Bioavailabilty
Permethrin has a relatively high log K_{ow} value and therefore has a high tendency to sorb to dissolved and particulate organic materials. The authors correctly point out that although ingestion of contaminated particles and food sources is likely an important route of exposure, it is not possible at this time to incorporate this pathway into criteria due to the lack of sufficient quantitative studies. Using the dissolved phase of permethrin to assess compliance is appropriate and will require site-specific data on water characteristics.

Isolation of the dissolved phase of permetrhin by solid-phase micro-extraction presents a practical approach for approximating the bioavailable phase of this compound. Determination of site-specific dissolved concentrations of permethrin may not be practical, however, due to the need for accurate measurements of dissolved organic compounds and suspended solids, which require significant effort to acquire. The fact that these parameters can vary spatially and temporally further complicates such assessments and should be mentioned here.

Mixtures
Additive and synergistic toxicity effects in the presence of other pesticides have been reported for permethrin. Because a variety of potential interactions are possible, it is not practical to apply a single model to predict toxicity at this time.

Temperature, pH effects
An inverse relationship between pyrethroid toxicity and water temperature is well documented. This relationship is important as laboratory toxicity tests are often conducted at temperatures that are higher than those in natural ecosystems. Although sufficient data does not exist to enable accurate predictions of temperature-related toxicity due to permethrin in aquatic ecosystems, this relationship should be considered in the derivation of safety factors as it is likely that criteria derived from laboratory studies conducted at relatively high temperatures will under-predict toxicity in many natural environments.

Permethrin does not undergo significant hydrolysis and pH does not appear to significantly influence its environmental fate.

Sensitive species
The calculated acute and chronic criteria (10- and 2-ng/L, respectively) are both below the lowest reported acute value of 21.1 ng/L reported for an amphipod. The chronic criterion is also below the lowest reported maximum acceptable toxicant concentration of 16 ng/L reported for a marine mysid shrimp. The conclusion that both the calculated acute and chronic criteria derived in this report should be adequately protective of aquatic environments is appropriate.

Ecosystem and other studies
The authors reviewed several studies that evaluated potential ecosystem impacts of permethrin in mesocosms and ecosystems. Impacts on invertebrates were only noted at concentrations of permethrin that exceeded the proposed acute and chronic criteria. The studies support the use of dissolved permethrin as the principal exposure medium.

Threatened and endangered species
Fish (*Oncorhynchus spp.*) that are listed as endangered in California are represented in the data set that was used to derive the acute criterion. Because fish in general, and these species specifically, are relatively insensitive to permethrin, the proposed acute and chronic criteria are protective of these species. Data for other threatened or endangered species, including plants, were not in the data set and appropriate surrogates were not available. Accordingly, specific conclusions could not be offered for these species. However, the mode of action of permethrin indicates that it should not be highly toxic to plant species.

Bioaccumulation
Permethrin has a high K_{ow} and therefore a high potential to bioaccumulate in aquatic organisms. Reported bioconcentration factors are consistent with this K_{ow} and a bioaccumulation factor (BAF) approach was used to estimate the water concentration of permethrin that would result in a lethal concentration in wildlife that would consume contaminated fish. A NOEC value of 125 mg/kg for mallard ducks was used in this calculation. Because this was the highest dose tested, a higher NOEC is probable. Using this approach, a water concentration of at least 4.46 µg/l would be required to produce a body burden of permethrin in fish that would be below the toxic threshold for mallards. This result clearly indicates that toxicity to mallards via food web transfer is unlikely. The high likelihood that such a water concentration, which is close to the aqueous solubility of permethrin and would be acutely lethal to prey species, including fish, should be mentioned.

Harmonization with air and sediment criteria
Sediment and air quality standards for permethrin do not exist. However, because permethrin has a relatively high partition coefficient, dissolved concentrations may serve as a proxy for sediment burdens if Koc values are available for a given site. This is consistent with the previous discussion of bioavailability.

Limitations, assumptions, and uncertainties
The authors correctly point out that the major sources of uncertainty in this evaluation stem from three of the five taxa requirements not being met for the chronic toxicity data set. The approach used (i.e., ACR) is appropriate given this limitation. The potential effect of lower temperatures on permethrin toxicity is potentially significant and should be considered in criterion development as more data becomes available.

Comparison to national standard methods
EPA (1985) methods were also used to derive acute and chronic criteria for permethrin. The EPA method faces the same limitation encountered in this report, that is, lack of data for all required taxa. The acute criterion proposed in this study is identical to the EPA-derived value for invertebrates (10 ng/L). A chronic criterion could not be calculated by the EPA method due to the lack of sufficient ACR data.

Final criteria statement
The recommended acute criterion is equivalent to the standard derived using EPA criteria. As proposed, the acute criterion of 10 ng/L and the chronic criterion of 2 ng/L should be protective of aquatic species in the Sacramento and San Joaquin River basins. The statement that the criteria were derived to be protective of aquatic life in the Sacramento and San Joaquin Rivers is a bit misleading, however, as the criteria were not derived exclusively using endemic species. The criteria were in fact derived for a generic freshwater North American ecosystem. The authors appropriately point out that the robustness of the derived criteria is limited by available data and should be updated as new information becomes available.

Typographical corrections

Table 4: For the column header “Chemical grade,” “Chemical” needs to be on the same line.

Table 9: For the column header “Chemical grade,” “Chemical” needs to be on the same line.